Temporal Variation in Polynesian Fishing Strategies: The Southern Cook Islands in Regional Perspective

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FISH AND FISHING have been an integral thread in the weft of Polynesian life over the last 3500 years. Although animal domesticates were important in social and ritual contexts, fish has been the protein mainstay throughout much of the region's prehistory. Historically Polynesian archaeologists have been more interested in fishing tools than fishing strategies and subsistence per se. Stylistic features of fishhooks, for example, have been key chronological markers, particularly in East Polynesia where they are abundant elements of the artifact assemblages (e.g., Davidson 1968; Emory et al. 1968; Sinoto 1962; Suggs 1961). Fishhooks have also figured prominently in attempts to trace ancestral relationships and postsettlement interaction (e.g., Golson 1959; Green 1968; Sinoto 1968; and more recently, Kirch et al. 1990:12).

Beginning in the 1970s, interest turned to functional aspects of fishing technology. Of particular note is Reinman's (1970) study of the ecology and mechanics of shell fishhooks. Reinman (1970) offered several thoughtful insights on relationships between varied functional attributes of hooks (e.g., size, shank-to-point ratio, overall curvature, point morphology) and their performance in fishing (e.g., ability to penetrate, holding properties, and aspects of hook strength). Analysis of fish fauna also became increasingly important beginning in the late 1970s (e.g., Barnett 1978; Kirch and Dye 1979; Leach and Anderson 1979; Leach and Davidson 1977). These faunal analyses provided independent monitors of fishing technologies that could then be compared with the artifact assemblages. Paralleling theoretical trends in the discipline at large, the role of local ecology in shaping fishing strategies and tool kits was increasingly recognized, as for example, Kirch's (1982*a*) study of fishing strategies in diverse marine environments of the Hawaiian Islands.

Processual questions of long-term change in Polynesian fishing practices have only begun to be explored. Recent studies emphasize the early period of island colonization and human impact on virgin terrestrial and coastal strand resources such as turtles, sea mammals, and shellfish (e.g., Dye and Steadman 1990; Kirch 1984; Kirch and Yen 1982). The overall importance of fishing relative to other subsistence activities has also seen some discussion (ibid.). However, aspects of temporal variability

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Asian Perspectives, Vol. 31, no. 2.

in fishing practices, changing patterns of prey, and the articulation of fishing strategies with other cultural and environmental processes have been neglected. Discussions of temporal variability in Marquesan fishhook morphology, first by Kirch (1980) and later by Dye (1990), are notable exceptions in this regard. In this paper I begin to explore spatial and temporal trends in shell fishhook technology and related patterns in prey capture.

THEORETICAL CONSIDERATIONS

A particularly elegant framework from which to consider processual questions is provided by Darwinian evolution (Dunnell 1980, 1982; Rindos 1984). In the Pacific, a Darwinian perspective has brought fresh insights to old problems, as, for example, the work of Hunt (1986), Hunt and Graves (1990), Kirch (1980), Kirch and Green (1987), and Terrell (1986). This framework incorporates both culture historical interests in long-term trends and the New Archaeology's emphasis on functional and systemic issues. In all three approaches, empirical variation is afforded a central role. Cultural historians emphasized the waxing and waning of stylistic traits as markers of passing time, while culture reconstructionists (after Dunnell 1978) stressed the interrelatedness of cultural traits and the role of the environment in effecting cultural change. However, both culture history and culture reconstruction focus on successful variants while more minor forms are often overlooked or considered noise. In so doing, the *product* (i.e., modal tendencies) rather than the *process* of change becomes the object of study. This practice has sometimes led to faulty interpretations, where internal temporal change is attributed to external forces (see discusssion in Hunt 1986, 1987). In other cases, archipelago-wide generalizations have masked significant spatial variability at the local level, variability that may reflect important differences in the conditions and process of adaptative change (see discussion in Kirch 1982*a*). The critical point of evolutionary theory is that the full range of cultural variation must be considered. By tracking the appearance, persistence or extinction, and changing frequencies of all variants we begin to tease apart the mechanics of cultural change and the conditions of long-term stability.

Documenting a source of variation (internal or external) and the distributional patterns of that variation (stylistic or functional; after Dunnell 1978; Jelinek 1976) are the first steps in providing evolutionary explanations. From this documentation of variability follows an evaluation of the mechanisms that may have shaped that variation through time. Biologists have proposed a number of evolutionary mechanisms that include not only natural selection, but also drift (including founder effect and other random processes), mutation, and pleiotropy. Much anthropological effort has recently focused on further developing evolutionary theory to accommodate properties common (but not necessarily unique) to human populations. At issue have been variations in the scale of selection (Dunnell 1988), an expanded definition of phenotype (Leonard and Jones 1987), and differences in the kind and rate of transmission (Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981).

Problematically one key evolutionary concept, adaptation, has seen widespread but sometimes inappropriate use in the archaeological literature. The problem arises when change is relegated to forces of human intention, wherein people consciously adapt as they see necessary. This overlooks the fact that although people make decisions they cannot control the long-term outcome of those decisions. In an evolutionary framework human decisions are more appropriately viewed as a source of variation, rather than a force of change (see O'Brien and Holland 1990).

In this paper I use theoretical concepts derived from Darwinian evolution to guide my examination of the Polynesian record of fishing technology. I begin by exploring temporal and spatial variation in shell fishhook assemblages and offer a series of hypotheses as to why this variation is patterned in a particular way. I then propose some selective conditions that may have prevailed at the time of East Polynesian colonization and led to increases in the frequency of angling. From there I turn to late prehistoric fishing patterns and evaluate the relative costs and benefits of particular technologies, taking into consideration both the larger subsistence context and the late prehistoric sociopolitical environment.

BROAD-SCALE REGIONAL PATTERNS IN FISHING TECHNOLOGY

Human colonization of the Polynesian region was quite rapid and is marked by a distinctive dentate-stamped pottery known as Lapita. By 3000 B.P. human populations had settled many if not most West Polynesian islands, spreading as far eastward as Samoa (Kirch and Hunt 1988). Linguistic reconstructions (Pawley and Green 1984) suggest that Lapita populations used nets, traps, angling, and poisoning in fishing—forms known at European contact across the region. Lapita faunal assemblages from West Polynesia reflect an emphasis on inshore species, particularly those commonly taken with nets and spears (e.g., Green 1986; Janetski 1980; Kirch and Dye 1979). The herbivorous, schooling parrotfish (scarids) are among the most abundant families in several Lapita assemblages (Butler 1988:114).

Although angling was practiced, it was apparently a relatively minor fishing strategy, given early West Polynesian artifact assemblages. Fishhooks are not only infrequently found (e.g., Green and Davidson 1974) but also occur in small numbers, even in more favorable preservation contexts (e.g., Kirch in press; Kirch and Yen 1982). In these early West Polynesian assemblages fishhooks were often manufactured from one or more species of *Turbo*, including *T. marmoratus* and *T. setosus*. The former species is quite large, with specimens reaching up to 210 mm in diameter (Eisenberg 1984:43). Although *T. marmoratus* is found in East Polynesia (Richard 1985), it is not abundant. The second species of *Turbo* also has a wide geographic distribution and, judging from its prevalence in Polynesian invertebrate assemblages, is usually locally abundant and accessible. However, *T. setosus* only reaches a maximum of 80 mm across (Eisenberg 1984:44). Hooks of the other shells, such as the lustrous bivalve pearl-shell (*Pinctada margaritifera*), are much less common.

The rarity of fishhooks in early West Polynesian assemblages is most striking in comparison to those from early East Polynesian contexts. Following colonization of East Polynesia (Fig. 1), sometime before 2000 B.P. (see Chikamori 1987; Kirch 1986; Ottino 1985), there was a virtual explosion of shell hook technology. Early East Polynesian assemblages (e.g., those dating from ca. 2000 to 1000 B.P.) from the Marquesas (Rolett 1989; Suggs 1961), the Societies (Sinoto 1988), and more recently the southern Cooks (Allen 1992; Allen and Schubel 1990; Steadman and Kirch 1990) display an abundance of fishhooks in an array of sizes and shapes. A second important contrast with West Polynesian assemblages is the predominant use of pearl-shell (specifically *Pinctada margaritifera*) rather than *Turbo*, as a raw material.

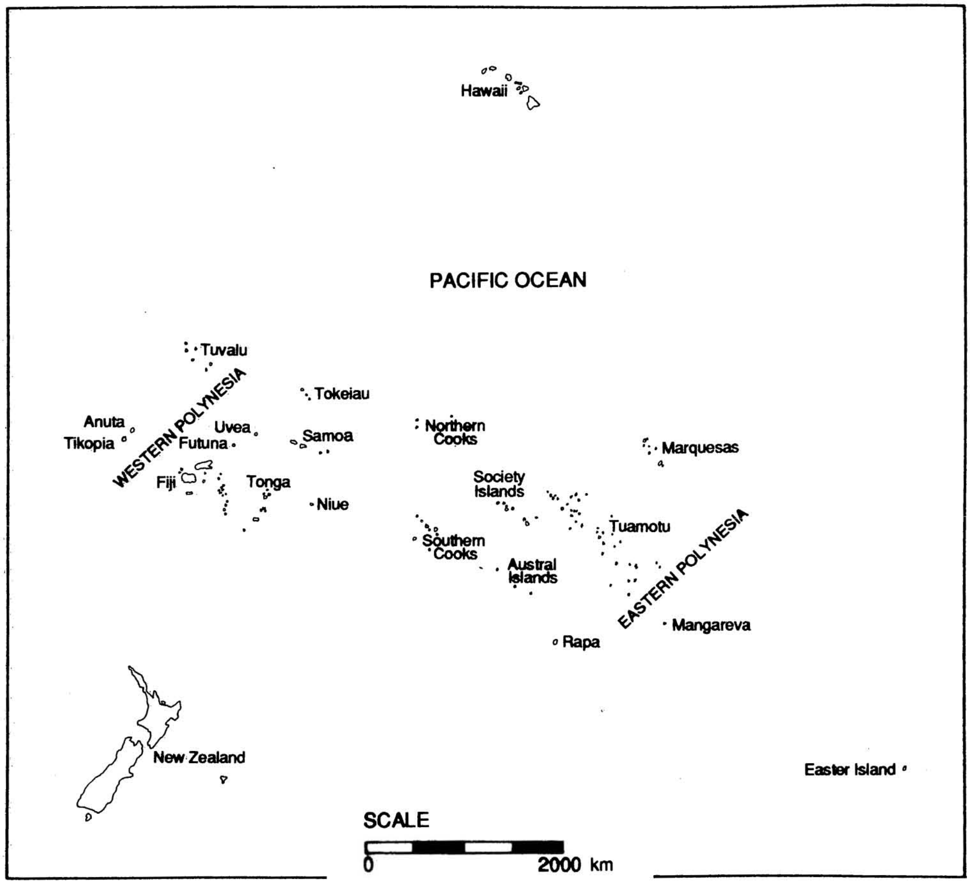


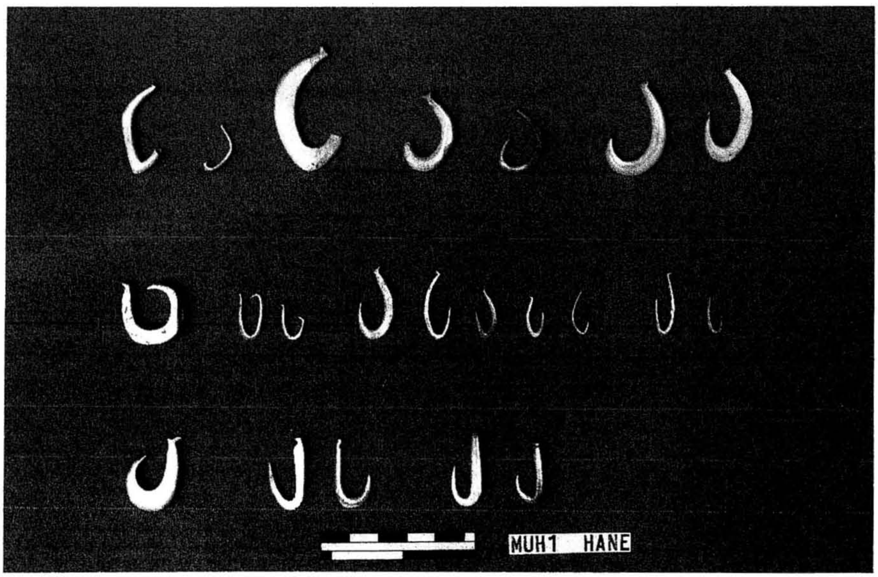
Fig. 1. Map of Polynesia showing East and West subregions.

Both the diversity of hook forms and their abundance in East Polynesia seems to be strongly tied to the increased availability of a critical resource, namely pearl-shell. Although pearl-shell is found in West Polynesia, large, dense beds of this species are seen only in East Polynesia, most notably in the Cook Islands and parts of French Polynesia (Salvat 1980:135). This simple change in raw material abundance apparently allowed for changes in hook technology that led to increases in the frequency of angling, previously a minor fishing technology. I suggest that some combination of workability, properties of strength and resiliency, and possibly lure qualities made pearl-shell a superior raw material. If this was the case, these attributes would have translated into greater flexibility in hook design, fewer mechanical failures and lower replacement costs, and better capture rates.

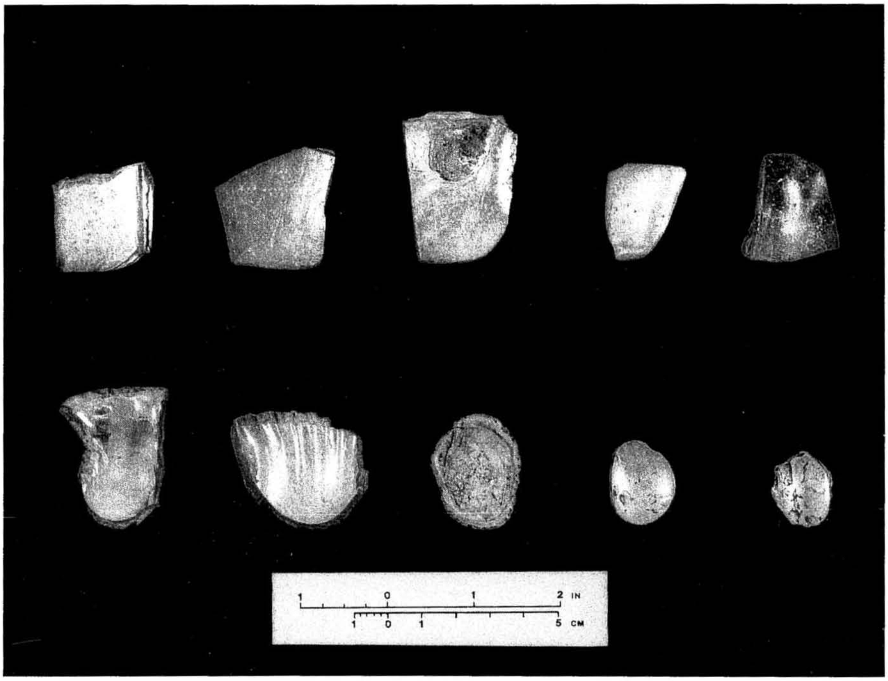
Ideally these hypotheses of physical differences should be evaluated through mechanical tests of sheer and tensile stress, as well as behavioral experiments in manufacturing costs and capture rates. Nevertheless, some supporting evidence is at hand. Molluscan skeletal structures are quite varied and have been studied extensively by both biologists and structural engineers. *Turbo* and *Pinctada* represent two different basic shell structural types. *Turbo* has a composite structure that includes both an outer prismatic layer of aragonite and a pearly inner laminar layer (Hickman and McLean 1990: 14). This inner laminar layer is also overlain by a very thin oblique or inclined prismatic layer. According to Hickman and McLean (1990: 14), the prism substructures of the trochacean superfamily are too poorly studied to detail. However, the *Turbo* shell structural type in general is very hard and therefore resistant to abrasion, but not very elastic (Dodd and Stanton 1990: 144). Pearl-shell, in contrast, is a nacreous structure in which the tabular aragonite crystals are arranged in layers with an organic matrix (Dodd and Stanton 1990: 144). These nacreous structures are the most resistant to breakage in tension, compaction, impact, and bending (Dodd and Stanton 1990: 146). These differences in basic shell structure undoubtedly affected both the production and the use of Polynesian hooks.

Turning to the archaeological evidence, we find that hooks made from *Turbo* are comparatively simple in design, and only a limited number of morphologies are found across the region (e.g., Kirch 1988; Kirch and Rosendahl 1973; Kirch and Yen 1982; Kirch et al. 1990). This is generally true of *Turbo* hooks from both early West Polynesian and late East Polynesian occupations (e.g., Allen 1992; Rappaport et al. 1967; Sinoto 1968). This raises the possibility that *Turbo* may not have easily lent itself to the range of curvaceous and complex shapes that are so often seen in pearl-shell hooks (Pl. I). Considering the structural properties of *Turbo*, particularly its hardness, the limited range of hook shapes may stem from the difficulty in working this raw material. The usefulness of *Turbo* as a raw material may have been further limited in the islands of East Polynesia where the larger species (*T. marmoratus*) is uncommon.

Excavation evidence from the Moturakau Rockshelters on Aitutaki, where a number of shell tablets for hook manufacture (i.e., blanks) were found (Pl. II), also speaks to raw material constraints (Allen 1992). In the case of *Turbo*, 25 blanks were



Pl. I. Typical example of morphological diversity seen in East Polynesian pearl-shell fishhook assemblages. All from Hane, Marquesas. (Photograph courtesy of Y. Sinoto.)



Pl. II. Tablets of shell, commonly referred to as blanks, prepared for fishhook manufacture. *Top row*, *Pinctada margaritifera* (pearl-shell); *bottom row*, *Turbo setosus*. These examples recovered from Aitutaki, southern Cook Islands.

recovered along with only six finished hooks, The pearl-shell ratio, in comparison, was one blank to 6.5 completed hooks. In other words, many *Turbo* blanks were being produced but only a few became finished products. This raises the possibility that attempts to produce *Turbo* hooks more frequently ended in failure.

Ethnographic accounts point to potential differences in the luring qualities of *Turbo* relative to pearl-shell (Nordhoff 1930). In discussions of bonito lures, informants recognized up to 15 different "varieties" of pearl-shell. Each shell variety came in three or more color morphs and each had a name, as, for example, *iri ahia'a* or "skin of the rose apple." Based on both informant accounts and Nordhoff's own fishing experiences of eight years, these subtle differences of color and sheen were recognized by the fish as well (Nordhoff 1930:242–243). Thus, there may be not only structural differences in *Turbo* and pearl-shell but also differences in their success rates with respect to prey capture.

These foregoing hypotheses are corroborated by recent findings from the Manu'a Islands of American Samoa. At the To'aga site on Ofu Island, Kirch and associates (Kirch and Hunt in press; Kirch et al. 1990) recovered a fishhook assemblage that is unusually large by West Polynesian standards. Consisting of 28 *Turbo* shell hooks and fragments, the one-piece specimens are "remarkably uniform in size and morphology" (Kirch et al. 1990:9) as would be predicted by the foregoing model. As on Aitutaki, the ratio of *Turbo* blanks to hooks is nearly four to one, again suggesting that *Turbo* may be a difficult material to shape into fishhooks. Kirch et al. (1990:11) further suggest that the To'aga hooks "might well be regarded as the kind of assemblage from which early East Polynesian fishhook complexes were derived," a point that seems quite probable in light of the foregoing discussion.

After human dispersal to the far outreaches of the East Polynesian region, other noteworthy changes in fishhook assemblages are found. These are most striking in archipelagoes where the availability of pearl-shell is once again limited. In Easter Island, shell hook technology is transferred to stone (Ayres 1979). In the Hawaiian Islands, pearl-shell hooks are found in early assemblages but are later replaced by bone hooks (Emory et al. 1968:31–32). This is especially true on the pearl-shell–poor islands of Maui, Hawai'i, Lāna'i, and Moloka'i. Although bone may be stronger than pearl-shell (Reinman 1970), it is considerably more difficult to work, taking at least twice the time needed to shape a shell hook (T. Maeva, pers. comm. 1991). Bone also lacks the lustrous sheen of pearl-shell that made it such an effective lure. It is interesting that the innovation of two-piece hooks appeared independently in Hawai'i, Easter Island, and New Zealand, all localities where pearl-shell was not readily available (Kirch 1982*b*). This artificial "breaking" and then lashing at the point of greatest stress, the bend, made for a stronger hook overall. These two-piece hooks may have been particularly important for conditions where currents were strong and the prey was large.

To this point, I have hypothesized that there are structural differences in the two primary raw materials used in Polynesian fishhook manufacture. These structural differences, coupled with the variable geographic distribution of pearl-shell, were important factors that affected the replicative success (after Leonard and Jones 1987) of fishhooks, and by extension, the success of angling strategies. It is useful at this juncture to compare these regional geographic patterns with the temporal sequence from Aitutaki, an East Polynesian island where pearl-shell was initially abundant but declined through time.

TEMPORAL PERSPECTIVES FROM AITUTAKI, SOUTHERN COOK ISLANDS

Environmental Context and Settlement History

The southern Cook Islands lie at the western edge of the East Polynesian region (Fig. 2). The archipelago is geographically separated from the islands of West Polynesia by a 1500-km stretch of open water, interrupted only by isolated Niue Island. The southern Cooks are geologically quite varied, with one volcanic high island (Rarotonga), three atolls (Manuae, Palmerston, and Suwarrow), one almost-atoll (Aitutaki), and four *makatea* or raised limestone islands (Mangaia, Atiu, Mitiaro, and Ma'uke). As might be expected, the marine habitats associated with these islands also vary significantly.

Of particular interest here is the island of Aitutaki, where archaeological excavations were carried out in 1987 and 1989 (Allen 1992). The dominant physiographic feature of Aitutaki is its large but shallow lagoon (10 m maximum depth), which is surrounded by a reef 45 km long. The Aitutaki mainland is the weathered remnant of an old volcanic cone. Fourteen named islets lie along the reef, and two small volcanic islets are found within the lagoon near the southern end.

The earliest cultural occupations in the southern Cooks date to ca. 1000 B.P. and are found on the islands of Aitutaki (AIT-10 in Fig. 2) and Mangaia (Allen and

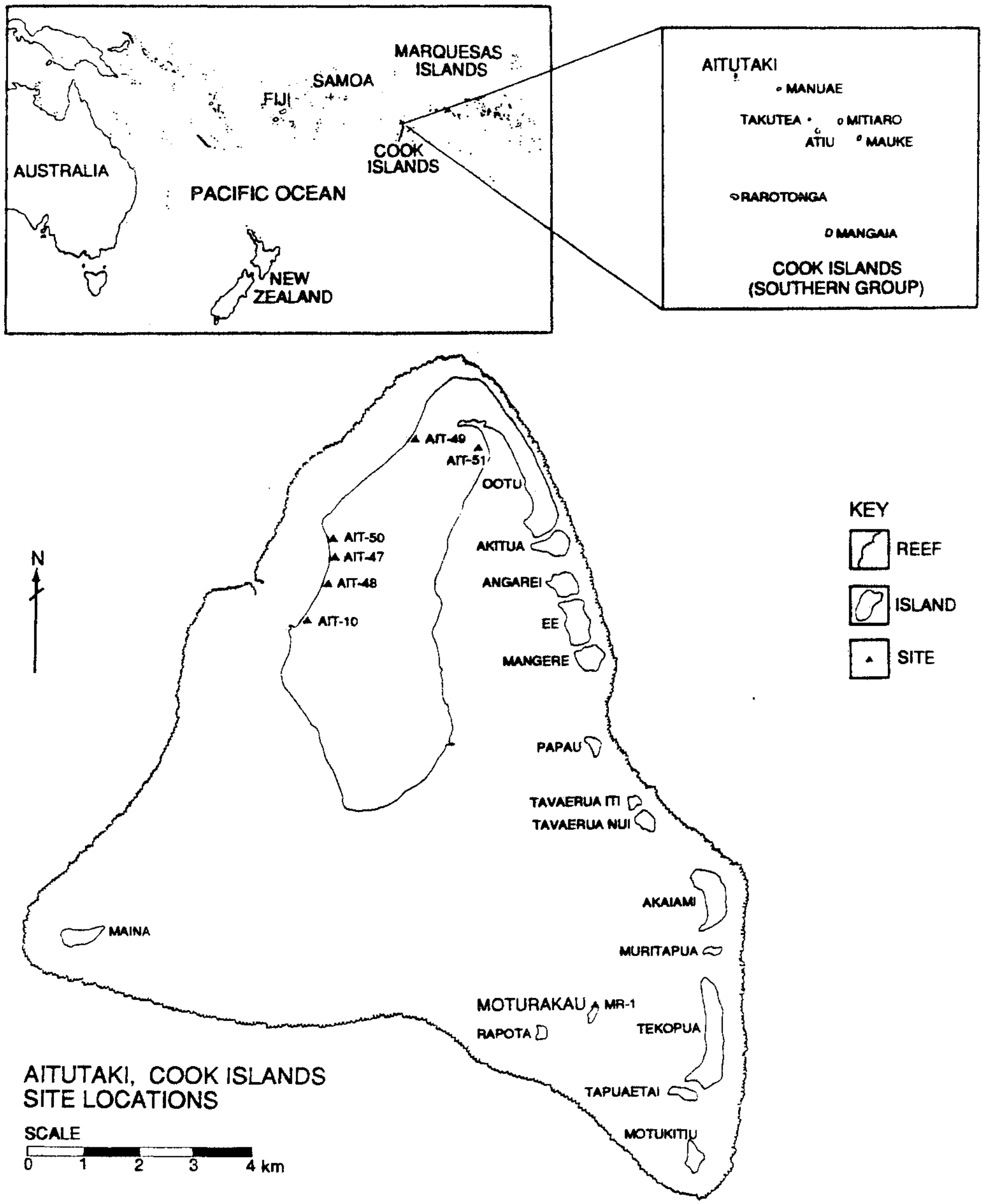


Fig. 2. Map of Aitutaki Island, southern Cook Group, showing primary excavation localities.

Steadman 1990; Steadman and Kirch 1990). However, pollen cores from Mangaia (Kirch et al. 1991) point to human activity possibly as early as 1600 B.P. Covering a 6000-year period, the Mangaian core is marked by significant forest declines at 1600 B.P. with no subsequent regeneration. At the same time, fern cover, of the type often indicative of secondary vegetation, increased in abundance. Together the two conditions point to the likelihood of a human presence.

On Aitutaki human colonization before 1000 B.P. is strongly suggested by other kinds of biological evidence (Allen 1992). Beginning with the earliest known settlement, the wood-charcoal record is already dominated by a limited number of species. It is significant that several of these taxa are economically important. The dominant elements include the coastal/secondary woody *Hibiscus*, the native hardwood *Calophyllum*, domesticated breadfruit (*Artocarpus altilis*), and a palm, most likely coconut (*Cocos nucifera*). The paucity of primary native forest species (other than *Calophyllum*) suggests that by the eleventh century A.D. much of Aitutaki's lowland, and possibly the interior areas, had been deforested. The predominance of economically important taxa may also point to a shortage of alternative fuel resources even at this relatively early period.

The Aitutaki land snail assemblages also indicate a strongly anthropogenic landscape at 1000 B.P. (Allen 1992). Adventive species thought to be Polynesian introductions dominate, including *Gastrocopta pediculus*, *Lamellaxis gracilis*, *Lamellidea pusilla*, and *Tornatellides oblongus*. Specimens of the large, arboreal *Partula*, which would be expected in areas of native forest, are found only in the basal occupation layers and only in small numbers.

The pre-Contact avifauna of Aitutaki speaks to a human-dominated environment over the last 1000 years as well. No native landbirds are found on the island today. Two taxa (*Porzana tabuensis* and *Dendrocygna* sp.) were recovered archaeologically, along with two locally extirpated seabirds, (*Pterodroma tahitiensis* and *Sula sula*) (Steadman 1991). The native fruit bat (*Pteropus tonganus*) was also present. As might be expected, most of these finds date to the early part of the occupation sequence. The recovery of extinct and extirpated species is consistent with early occupations elsewhere in the region (Steadman 1989). However, in the Aitutaki case, both the small number of taxa and the limited quantity of materials suggest that we are seeing the end of the process of local extinction (Allen 1992). Overall, the strongly anthropogenic character of Aitutaki's early wood-charcoal and land snail records, coupled with the depleted avifauna, suggests that people had colonized the island at least a few centuries before 1000 B.P.

Thus, although the earliest archaeological deposits presently known from the southern Cooks date to 1000 B.P., there are several indicators, from at least two islands, that suggest human colonization before that time. Given occupations in the northern Cook Islands and in the Marquesas before 2000 B.P. (Chikamori 1987; Kirch 1986; Ottino 1985), it would not be surprising if comparably early deposits were found locally. Indeed, the fishhook assemblages from East Polynesia suggest that the earliest regional assemblages also remain unidentified (see below).

Ethnographic Patterns of Fishing

It is useful to examine the early ethnographic fishing patterns of Aitutaki as the endpoint of the indigenous sequence. Information on traditional fishing technologies comes from the early-twentieth-century studies of ethnologist Peter Buck (1927). Although not immune to European influences, Aitutaki fishing practices at that time were still largely reliant on local materials and traditional technologies. Buck recorded 28 strategies that used nets ($n = 7$), weirs ($n = 5$), hooks ($n = 4$), torches ($n = 3$), traps ($n = 2$), leaf sweeps ($n = 2$), nooses ($n = 1$), and spears ($n = 1$). In addition, diving and hand-grouping were two techniques requiring no specialized equipment.

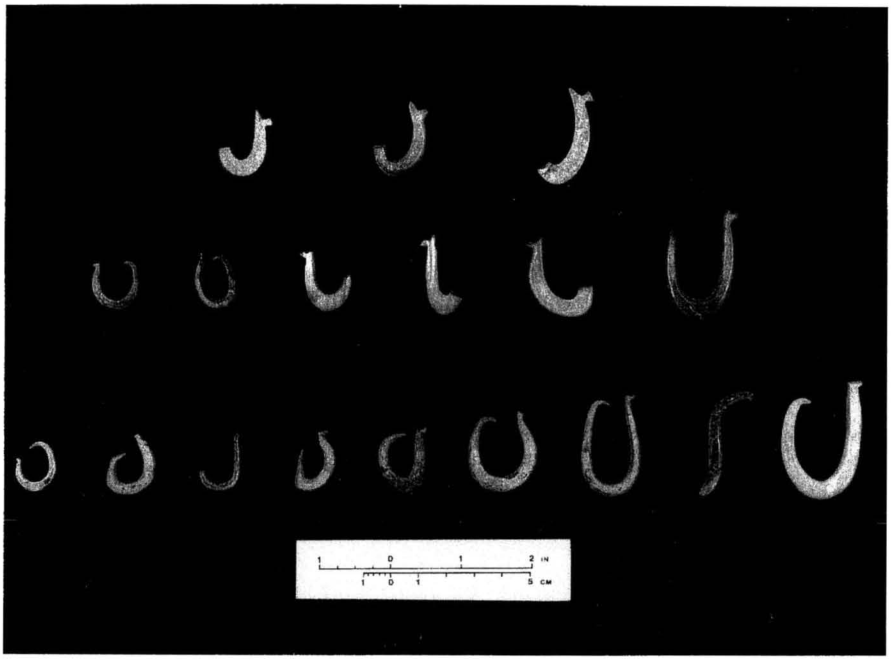
At the time of Buck's (1927) study, nets and weirs were the dominant fishing technologies. Buck (1927:280) noted that the people of Aitutaki were particularly proud of their nets and continued to use traditional manufacturing techniques, which they considered superior to European methods. Seven different kinds of nets were produced, including large seine nets, short set nets, and scoop nets (Buck 1927:277–297). These were often used in conjunction with fish weirs. Fish weirs were essentially open-ended pens of dry-stone masonry, constructed on the wide reef flats. Each weir was built to incorporate a natural channel that led to the open sea. These facilities were named and owned by particular families.

According to Buck (1927:306), angling was the least important method of fishing on Aitutaki. Only four hook forms were known at the time of his study, and one of these was made of metal. Captain Bligh of *Bounty* fame (in Lee 1920:134) reported turtle-shell hooks from Aitutaki, but no details as to their form or use are known. A high chief of Rarotonga was of the opinion that only the three large wooden hooks were native to the southern Cooks (in Buck 1927). Given the ethnographic record, it was therefore surprising when our archaeological excavations turned up an abundance of shell fishhooks.

Temporal Trends in Technology

On Aitutaki, shell hooks are most common in the earliest occupations, particularly the basal strata of the Moturakau Rockshelters (MR-1). The earliest specimens are made almost entirely from pearl-shell, although a few fragments of *Turbo* hooks indicate that information on their manufacture was retained. Morphologically the earliest hook assemblages are quite diverse, with an array of sizes and shapes, although only one-piece forms were present (Pl. III). Similar assemblages are known from contemporaneous contexts on Mangaia (Steadman and Kirch 1990) and from a thirteenth-century occupation on Ma'uke (Walter 1990). In the Ma'uke case, pearl-shell tools are not limited to fishhooks, but also include ornaments, an awl, spear points, a grater, and a tattoo chisel (Walter 1990:195).

Beginning around 550 to 450 B.P., several changes occur in the Aitutaki sequence (Allen 1992). Fishhooks overall begin to decline, *Turbo* hooks and blanks become more common (although never abundant), shell hook morphologies become increasingly uniform, and there is limited evidence for experimentation with other shell species including *Modiolus*, *Conus*, *Asaphis*, *Pinna*, and *Periglypta*. Over the next few hundred years, pearl-shell hook manufacture declines dramatically, *Turbo* hook production persists, and there is at least one example of a breast plate ornament being recycled for hook manufacture. Declines in pearl-shell are also seen on Ma'uke and Mangaia, although the timing of these changes is currently unavailable. Shortly before Contact, shell hooks have virtually disappeared from Aitutaki's archaeological record.



Pl. III. Temporal variation in Aitutaki shell fishhooks, early forms (*bottom row*) to late forms (*top row*). Third and fourth specimens from left, *middle row*, are *Turbo* hooks.

It is important to point out that the Aitutaki trends are not artifacts of variable site locations, differential preservation, or changes in site formation processes. The bulk of the shell hooks come from the Moturakau Rockshelters, which provide a nearly continuous sequence beginning at ca. 750 B.P. and extending into the Contact period. Shell remains from dietary species are well-represented throughout, indicating that differing soil conditions (e.g., acidic A-horizons versus alkaline sands) are not differentially preserving shell hooks. Although there are some changes in the relative importance of depositional agents over the course of this roughly 700-year period, the shelters clearly acted as catchments for cultural remains throughout the sequence. Excavations both within and outside of the shelters also provide control over potential changes in the spatial use of the site through time.

The loss of pearl-shell hooks on both Aitutaki and Ma'uke appears directly related to declines in raw materials. On Ma'uke both pearl-shell hooks and other tools of the same raw material are altogether lacking from late prehistoric occupations (Walter 1990). On Aitutaki, large pieces of worked pearl-shell are only found in the earliest contexts and declines in both hooks and manufacturing debitage are seen at several localities (Allen 1992). Walter (1990:298) suggests that pearl-shell losses on Ma'uke, where the species does not naturally occur, are related to a breakdown of an archipelago-wide "network of interaction," which involved exchange. However, for Aitutaki, where pearl-shell is locally available even today, this explanation is insufficient.

Elsewhere (Allen 1992; Allen and Schubel 1990) I argue that these declines in pearl-shell are linked to changes in the local marine environment. In particular, gardening activities on the eastern side of Aitutaki may have accelerated terrigenous sedimentation to the lagoon. Given the shallowness of Aitutaki's lagoon (by atoll standards), this may have been a particularly fragile habitat from the time of earliest human settlement. Changes in the intensity of agricultural activities, or possibly the cumulative effect of several hundred years of erosion, could have altered pearl-shell habitat and led to local declines. Increased sedimentation could have affected lagoon substrate, salinity, temperature, turbidity, and circulation—all factors critical to the maintenance of pearl-shell stocks (Intes 1982). Although pearl-shell grows in waters as shallow as 1 m, Intes (1982) emphasizes the importance of deep-water habitats as a buffer against predators.

On Mangaia a similar sequence with a different outcome is found. Here pearl-shell hooks are common in the early occupations identified by Steadman and Kirch (1990) at Tangata Tau Rockshelter. As on Aitutaki, pearl-shell hooks are gradually replaced by ones made of *Turbo* (Kirch, pers. comm.). However, in contrast to Aitutaki, *Turbo* hooks continue to be used into the Contact period. With raw material replacement there is also a diminution of size that may be related to raw material size and/or may reflect changes in prey size. At European Contact, coconut-shell hooks were also widely used on Mangaia (Buck 1944:237–238; Gill 1880:212).

Notably, *Turbo setosus* is present in both the Aitutaki and Mangaian environments and is generally common throughout the region. On Aitutaki it is one of the dominant components of the archaeological shellfish assemblages, and is readily found on the reefs today. All other factors being equal (and my argument is that they were not), *Turbo* would have been a cheaper raw material because it was plentiful, easily accessible, and already gathered as a food. That the Aitutaki populations did not continue to manufacture *Turbo* hooks suggests that other critical factors were involved.

Temporal Trends in Prey

The Aitutaki faunal record provides another window on changing patterns of technology. It also points to a probable functional relationship between at least one fish group and pearl-shell hooks. The assemblages come from four localities, three located on the western coast of the mainland and a fourth from Moturakau Islet (see Fig. 2). A variety of vertebrate remains was recovered from these multi-occupation sites including not only fish but also pig, dog, chicken, rat, turtle, porpoise, fruit bat, and several native sea and land birds. Fish are a prominent component of all of the Aitutaki faunal assemblages, but especially so on Moturakau. With over 11,000 identified specimens from the two Moturakau units analyzed thus far, this is undoubtedly the largest archaeological fish assemblage in the region (Nagaoka 1992).

The large Moturakau assemblage is representative of the major island-wide temporal trends and is summarized here in Table 1. The most obvious pattern is the sustained dominance held by scarids (parrotfish) and serranids (groupers and cods), suggesting a degree of stability in fishing practices throughout the prehistoric period. The replication of this pattern across the four sites analyzed suggests that it is reliable, although the ranks of the two taxa do alternate with one another by occupation. The frequency of scarids suggests the use of inshore technologies, most probably nets and spears, beginning with the earliest occupations.

The persistence of serranids (groupers, rockcods), a group commonly taken with

TABLE 1. MOTURAKAU SHELTERS: RANK ORDER ABUNDANCE OF DOMINANT FISH FAMILIES

	ANALYTIC ZONE							
	ZONE B		ZONE C		ZONE D		ZONE F/H	
TAXON	RANK 1[a]	RANK 2[b]	RANK 1	RANK 2	RANK 1	RANK 2	RANK 1	RANK 2
Muraenidae	3	(2)	3	(4)	6	(3)		(4)
Belonidae			6				6	
Serranidae	1	(4)	1	(2)	1	(2)	1	(2)
Carangidae	4							
Lutjanidae					5		3	(6)
Mullidae	5		4		4		5	
Labridae	6		5		3	(5)	4	(5)
Scaridae	2	(3)	2	(1)	2	(1)	2	(1)
Acanthuridae		(5)		(5)		(4)		(3)
Balistidae		(6)		(6)				
Ostraciidae								
Diodontidae		(1)		(3)		(6)		

[a]Rank 1, five common elements.
[b]Rank 2, common elements and special bones.

hooks, is surprising in light of the artifact assemblages. These abundances point to several potential methodological problems. First, there is no deterministic relationship between fish species and methods of capture. In probabilistic terms, it can be argued that carnivorous fish, like the serranids, are most commonly taken by angling. However, ethnographic accounts show that these, as well as most other fish species, can be taken by varied technologies (e.g., Dye 1983; Green 1986).

A second potential problem relates to the level of identification routinely made in Pacific fish analyses. With a few exceptions, Pacific fish are only identified to the level of family. This in part reflects the small size of reference collections and, perhaps more important, the lack of comparative studies of subfamilial skeletal anatomy. As might be expected, family-level identifications can mask significant variability in habitat representation and in methods of capture. More detailed study may reveal that the Aitutaki serranids change through time from predominantly offshore taxa to species more commonly found in inshore waters.

Another methodological issue relates to the relatively generalized character of serranid skeletal anatomy. The archaeological implications of this are that most of the commonly identified elements are not particularly small, as in the case of acanthurids (surgeonfish), or particularly fragile, as with chanids (milkfish). Thus, serranid body parts may be more easily recovered from archaeological contexts depending on the conditions of preservation and recovery.

A second trend seen in the Aitutaki faunal evidence is a decline through time in the lutjanids (snappers). These wide-ranging carnivorous fish are often (but not exclusively) found in deep-water habitats (Parrish 1987:414–415). They are most commonly secured by angling techniques, although smaller species and immatures are sometimes caught in nets. What is perhaps most significant about the decline in snappers is its coincidence with decreases in pearl-shell fishhooks, strongly suggesting that there is a functional relationship between the technology and this prey.

More generally it suggests that shell hooks may have been used largely for deeper water and offshore species. Johannes's (1981:113–114) ethnographic study of traditional Palauan fishing technologies emphasizes the effectiveness of rotating hooks (which is the type most well-represented on Aitutaki) in deep-water contexts. Rotating hooks are also stronger, because stresses are more evenly distributed across the hook, and therefore more useful for large prey.

The third trend of importance here is the increase through time of at least two inshore species, the balistids (triggerfish) and the diodontids (porcupinefish). Both families are commonly taken with nets, and thus appear to mirror changes suggested by the artifact evidence. Also implied by the artifact and fauna evidence is a temporal decline not only in deeper water angling, but eventually in inshore angling as well.

Overall, the faunal assemblages suggest a temporal decrease in the frequency with which the outer reef and deeper water environments are used. The most prominent taxonomic change is in the importance of lutjanids. There are also some indications of an increasing importance of inshore technologies. However, the assemblages indicate that inshore technologies have been present and well-represented in the fishing repertoire throughout the prehistoric past.

POLYNESIAN FISHING: MECHANISMS OF CHANGE

The discussion thus far has shown how the frequency of shell hooks increases with the availability of pearl-shell and decreases when this resource is rare. The pattern appears to hold both across time and across space. However, the availability and structural properties of pearl-shell are only a source of variation and do not fully explain why angling, relative to other fishing technologies, varies in importance.

Early Conditions

Although many Polynesian archaeologists have remarked on the sudden burst of shell-hook technology seen with East Polynesian settlement, few have offered explanations for why this occurs. Kirch (1980), in considering the early Marquesan assemblages some ten years ago, suggested that morphological variability early in the sequence reflected a period of experimentation under conditions of environmental stress. He observed that in the steep rocky marine environments of the Marquesas, traditional West Polynesian technologies of netting, poisoning, and spearing were no longer effective.

Kirch's explanation may hold for the Marquesas, but I suggest an alternative model for East Polynesian patterns as a whole. Pearl-shell fishhook technology may have developed first not in the Marquesas, but in some as yet unidentified pearl-shell rich environment(s). Locally abundant resources would have allowed increased production of a technology that was previously present but relatively unimportant. The Nukuoro example (Davidson 1971) provides a potential model of changes in shell-hook technology under conditions of unlimited availability. Davidson (1971; see also Leach and Davidson 1988) found that a limited number of early forms ultimately gave rise to a more diverse assemblage that persisted into the Contact period.

Although fishhooks may have been developed initially for inshore species, as suggested by Reinman (1970), it appears that increased hook production was accompanied by innovations appropriate for angling in deep-water environments. Increased access to the outer reef zone and deeper offshore waters (but not necessarily the pelagic zone) allowed for more regular capture of large, high-quality prey such as snappers, emperorfish, groupers, and tuna. The initial selective advantages conferred to human populations by these new hook forms would have been more consistent access to high-quality prey during a period when terrestrial resources were being established and were probably less reliable. If this model holds true, at least some of the variability seen in the early Marquesan sequences may, by extension, be homologous in origin. Unfortunately the critical assemblages, those intermediate between early West Polynesian sites and the 2000-year-old East Polynesian sites, are largely lacking. The finds of Kirch and Hunt (in press) at To'aga, Samoa, however, are an important contribution in this regard.

Late Conditions

Late in Polynesian prehistory, fishing trends suggest that not only did pearl-shell decline but also the cultural environment of fishing may have changed. On Aitutaki, angling becomes increasingly rare, while nets, weirs, and other technologies come to dominate. Important in the rise of these inshore technologies is the character of the Aitutaki marine environment and in particular the availability of large reef flats, extensive sandy shoals, and the shallow lagoon where technologies other than angling are effective. On the raised limestone island of Mangaia, in contrast, only narrow fringing reefs are found. Here angling persists throughout the sequence, even after pearl-shell declines, using the inferior *Turbo* and other raw materials. Although small nets can be used in channels and on the reef flat, angling from the reef edge and canoes remains important on Mangaia even today.

In Table 2, I compare angling with nets and weirs in terms of several attributes. Nets and weirs represent substantial initial investments but require infrequent replacement and relatively low maintenance. Pearl-shell fishhooks, in contrast, take a skilled craftsperson only 4 to 5 hours to produce (T. Maeva, pers. comm.) but have high replacement costs given frequent losses or breaks during fishing (cf. Beasley 1928). Nets and weirs substantially increase productivity relative to angling

TABLE 2. COMPARISON OF ANGLING VERSUS NETS AND WEIRS: RELATIVE COSTS, BENEFITS, AND OTHER KEY ATTRIBUTES

	ANGLING	NETS AND WEIRS
Costs (−) and benefits (+)		
Equipment		
Manufacture costs	Low (+)	High (−)
Replacement rates	High (−)	Low (+)
Productivity per unit of time	Low (−)	High (+)
Selectivity of catch	High (+)	Low (−)
Associated risks	High (−)	Low (+)
Prey characteristics		
Typical prey type	Carnivores	Herbivores
Trophic level of prey	High	Low
Other attributes		
Social unit	Individual	Communal
Activity type	Mobile	Sedentary

strategies, but allow for much less control over the kind and size of the catch. Kirch (1979:295) notes that a communal fish drive on Anuta brought 90 kg of fish over a 2-hour period (see also Dye 1983:252). The prey taken by these two kinds of technologies also varies significantly. Nets and weirs tend to capture fish from lower on the food chain and are therefore more conservative in ecological terms.

Two other features of nets and weirs, relative to angling, also warrant consideration. First, nets and weirs are used in shallow waters near to the home base and involve less risk and uncertainty compared to offshore fishing. Risk specifically refers to the degree of stochastic variation in decision outcomes, while uncertainty arises from the imperfect quality of information available to decision-makers (see Stephens and Charnov 1982; Winterhalder 1987). In the case of fishing, risk includes the possibility of bodily harm and loss of equipment, while uncertainty relates to the possibility of an unproductive fishing expedition.

A second important distinction between angling versus nets and weirs relates to the social context of these two dichotimized technological groups. Specifically, the decline in angling represents a shift from individual strategies and gear to more communal ones. These communal facilities are both more sizable and semienduring, and often required labor parties ranging in size from several persons to whole communities. Overall, nets and weirs seem to offer some productive benefits over angling, particularly on the almost-atoll of Aitutaki. However, I suggest that the advantages of these late prehistoric shifts in technology, quality of catch, and social organization become most apparent when viewed within the context of the subsistence system as a whole, as well as the sociopolitical environment.

Returning to the region at large, two late prehistoric patterns are evident. First, several Polynesian island sequences are characterized by both increased energetic commitments to agriculture and expansion of agricultural activities to new areas. Without debating the dependent versus independent role of population in these changes, it is clear that domesticated carbohydrates are the most important subsistence element with respect to caloric nutrition. Only through manipulation of these domesticates, and their environments, could carrying capacity be significantly altered. A second regional pattern seen late in prehistory is increased competition and territoriality. Much of the competition is over land and specifically agricultural resources (e.g., Kirch 1984). These processes are archaeologically apparent in the establishment of physical boundaries, the appearance of fortifications, and Contact-period accounts of warfare and conquest.

On Aitutaki, little is known about the traditional agricultural system and how it has changed through time. As noted earlier, wood-charcoal, land snails, and the birds all suggest that by 1000 B.P. the native flora and fauna had been significantly altered. The only possible indication of intensified agricultural activities at this juncture is the demise of pearl-shell beginning around 600 to 500 B.P. and its possible link to lagoon sedimentation. Nevertheless, the regional patterns of increased competition and territoriality described above are well known from other southern Cook Islands (i.e., Mangaia and Rarotonga), and there is little reason to suspect that they were not operative on Aitutaki as well.

Given the critical relationship between plant carbohydrates and population, I argue that subsistence activities that compete with those of agriculture (i.e., in terms of time, energy, or risks) are the most likely to be dropped from the subsistence system. Those activities that do not compete will be more likely to persist. Furthermore, subsistence activities that interfere with a group's ability to defend its agricultural territories are more likely to be selected against.

Offshore and deep-water fishing, compared to inshore technologies, are more time-consuming, more risky and less certain, and particularly with declines in pearl-shell, more expensive to maintain. These technologies therefore potentially compete with plant domesticates in terms of labor, scheduling, and other resources. What appears to occur in fishing technologies, not only in Aitutaki but also elsewhere in Polynesia, is a gradual constriction of catchment areas through time. By the late prehistoric period, offshore trolling and deep-water fishing were on the decline, or no longer practiced, in several Polynesian islands, as for example the Marquesas (Dye 1990; Rolett 1989) and the Societies (Leach et al. 1984).

On Aitutaki, declines in shell hooks and the related patterns in snappers marks a reduction in the *frequency* with which the outer limits of the catchment, specifically offshore marine environments, are used. Contemporaneous with decreases in use of these deeper waters is the establishment of more permanent, communal facilities, under the control of specific social groups. In this sense late prehistoric fishing technologies mirror processes in terrestrial subsistence in their tendency toward territoriality. The construction of weirs is a demarcation of inshore waters that actively excludes other social groups and thereby: (1) ensures that some portion of the inshore areas will always be available to the adjacent settlements; and (2) reduces the uncertainty of prey capture that might prevail if movement and resource use were anarchic (see Smith 1988). The increased emphasis on nets and weirs also marks a decline in the mobility of fishing activities, with circumscribed, demarcated technologies such as weirs displacing more wide-ranging offshore ones. While nets and weirs are more productive technologies, they represent a loss in terms of the potential size and quality of the prey.

SUMMARY AND CONCLUSIONS

In conclusion, the broad-scale spatial patterns seen across the region, and the Aitutaki temporal sequence in particular, suggest that pearl-shell was a critical raw material in the production of angling gear. When pearl-shell increases in abundance with movement to the East, so does the abundance and diversity of fishhooks. On Aitutaki when this resource declines through time, hook assemblages become less abundant and eventually disappear. I argue that these changes in fishhook abundances are partially tied to differences in the structural properties of pearl-shell versus *Turbo*.

I have suggested that during the early period of East Polynesian settlement, pearl-shell hooks were favored because they offered better access to deeper-water habitats and the associated large, high-quality prey. However, through time the costs and benefits of angling relative to other technologies change. By late prehistory plant carbohydrates assume an increasingly crucial role in the subsistence system as an outgrowth of large populations and limited terrestrial resources. At this juncture, changes in fishing technology occur not because of functional advantages of particular technologies per se, but rather because of relationships with other subsistence and sociopolitical activities. When viewed from the larger functional network of the subsistence system, late prehistoric changes in fishing not only continue to be productive, but also enhance subsistence productivity overall.

ACKNOWLEDGMENTS

The Aitutaki research was largely funded by grants to the author from the National Science Foundation (BSN-8822768) and Wenner-Gren Foundation for Anthropological Research (5079) and NSF Grant BSR-8607535 to David Steadman. Additional support was provided by a W. W. Stout Fellowship from the University of Washington; Sigma Xi, The Scientific Research Society; the Thomas Burke Museum; and the Cook Island National Museum. I am grateful to the Cook Island people for their hospitality and friendship throughout the 1987 and 1989 field seasons, in particular Tony Utanga, Makiuti Tongia, the Aitutaki Ministry of Internal staff, and the Moturakau Islet landowners, the Bishop and Neale families. Lisa Nagaoka, Sue Schubel, and Algernon Allen assisted in the field work. The 11,000 Moturakau fish specimens were identified by Nagaoka; those from other sites were identified by the author. Land snail identifications were provided by Carl Christensen. Figures were drafted by Brad Evans. This paper was originally presented at the 1992 annual meetings of the Society for American Archaeology, "Subsistence and Environmental Change in Oceania" Symposium, organized by Lisa Nagaoka and Elizabeth Gordon. I thank the two symposium discussants, Patrick Kirch and Donald Grayson, for their critical insights. I also thank Michael Graves and Terry Hunt for their thoughtful comments on an early draft.

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ABSTRACT

Geographic variability in Polynesian fishhook assemblages has long been recognized but largely unexplained. West Polynesian assemblages are typically small in number, relatively uniform in morphology, and often manufactured from *Turbo*. Those from East Polynesia are comparatively large and morphologically varied, and *Pinctada margaritifera* is the preferred raw material. Drawing on both geographically dispersed assemblages and the temporal sequence from Aitutaki, Cook Islands, I suggest that these assemblage differences stem from both structural properties of the two shell species and their differential availability through time and across the region. I also examine two sets of selective conditions, one that initially led to an increase in the frequency of angling in East Polynesia and a second that subsequently fostered a decline in angling on Aitutaki and possibly elsewhere in the region.

KEYWORDS: Polynesian fishing, southern Cook Islands, fishhooks, technological variation, culture process.